Synergistic effect of benzolinone with IBA and fungicides on the vegetative propagation of ornamental plants, park, and fruit woody species

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ABSTRACT: A study was made of the stimulating effect of benzolinone (3-benzyloxycarbonyl-methyl)-2-benzothiazolinone in powder form (P) and its mixture with indole butyric acid (IBA), the biofungicide Supresivit and fungicide Captan 50 WP on the root formation of 17 species of ornamental plants, park and fruit woody species. Under the action of benzolinone, the yield of rooted cuttings in the category of ornamental plants amounted to 44.5% (in the *Dianthus* sp.) up to 83.7% (in *Rosa canina*), in the category of park woody species it was from l6.7 (in *Magnolia stellata*) to 100% (in *Forsythia intermedia*). In fruit trees represented by two species, viz. *Actinidia arguta* and cherry rootstocks, the yield was between 20 and 86.7%, and in two allochthonous species *Cotoneaster horizontalis* and *Philadelphus coronarius* it was from 96.7 to 100% in rooted cuttings. In the case of herbaceous and semi-lignified cuttings, lower concentrations of benzolinone below 0.1% were more effective, while on the contrary, higher concentrations of 0.1–0.2% proved more effective with lignified cuttings. In the species with difficult root formation, such as *Magnolia stellata*, *Viburnum farreri* and *Actinidia arguta*, benzolinone demonstrably stimulated both the rhizogenesis, and thereby the overall yield of rooted cuttings, and the quality of the root system. In the case of the species with naturally high rooting ability, the positive effect of benzolinone was manifest mainly in the quality of the root system. The synergistic action of the above stimulants on root formation was achieved in two and three-component benzolinone mixtures with IBA and fungicides on the basis of the active ingredients captan and *Trichoderma harzianum*. The most evident stimulating effects on the rooting of cuttings in *Dianthus* sp., *Ficus schlechteri* and the deciduous species *Acer saccharinum Pyramidale*, *Prunus padus Colorata* and *Prunus kurilensis Brilliant* was obtained in three-component mixtures.

Keywords: benzolinone; indole-3-butyric acid (IBA); captan; *Trichoderma harzianum*; vegetative propagation; ornamental plants; park and fruit woody species

Stimulation of rhizogenesis with the use of biologically active substances currently represents an effective method of vegetative propagation of plants. To this end, a whole series of active substances is used (Fibijian et al. 1981; Davis, Hassig 1990; Tantos et al. 2000). These are preparations based on auxinoids (Hassig 1974; Gaspar, Hofinger 1988), retardants (Upadhyaya 1986; Marino 1988; Davis et al. 1991; Šebánek et al. 1991; Tari, Nagy 1996) or their mixtures (Smith, Thorpe 1975; Obdržálek 1987; Pan, Zhao 1994).

Rastim 30 DKV is also one of the preparations used for the rooting of ornamental plants. Besides stimulation of the rooting of roses, chrysanthemums and carnations at concentrations of 0.03–0.003%, this preparation is also registered as a growth regulator of other plants (Dolinay, Kohaut 2000; Kupec et al. 2000). An active ingredient in the preparation is 3-(benzyloxycarbonyl-methyl)-2-benzothiazolinone, which has an action similar to that of auxin (Blažková et al. 1994; Henselová, Konečný 1995) and was verified in a dispersion liquid form (DKV) in plant rooting by Henselová et al. (1989) and Rauscherová et al. (1991). A wish to extend the spectrum of benzolinone use to stimulate rhizogenesis of the species in which a long-term stimulation in liquid solutions is unsuitable, and also an interest on the part of consumers in more effective stimulators, have created the need of adjusting this substance into powder form.

This study presents the results of six-year research on benzolinone and its mixture with indole butyric acid (IBA) and fungicides in powder form (P) with the aim to evaluate their effect in stimulating the rhizogenesis of ornamental plants, park and fruit woody species. The research carried out at several workplaces in the Slovak Republic and in the Czech Republic was meant to lead to the proposal of a prospective sample for state verification tests with the intent to have it registered.

MATERIAL AND METHODS

Benzolinone is a universal name for the active ingredient 3-(benzyloxycarbonyl-methyl)-2-benzothiazoli-

Dedicated to Prof. RNDr. Ľudovít Pastýrik, DrSc., on the occasion of his 90th birthday.

Table 1. List of samples of benzolinone and its mixtures used in final formulations of powder

Sample	Composition	Concentration (%)	Concentration of active ingredient (mg/kg)
B_1	benzolinone	0.01	100
B_2	benzolinone	0.05	500
B_3	benzolinone	0.1	1,000
B_4	benzolinone	0.2	2,000
B_5	benzolinone	0.5	5,000
M_1	benzolinone + IBA	0.09 + 0.01	900 + 100
M_2	benzolinone + captan	0.1 + 2.5	1,000 + 25,000
M_3	benzolinone + *T. harzianum*	0.1 + 2.5	1,000 + 25,000
M_4	benzolinone + IBA + captan	0.09 + 0.01 + 2.5	900 + 100 + 25,000
M_5	benzolinone + IBA+ *T. harzianum*	0.09 + 0.01 + 2.5	900 + 100 + 25,000
Control	pure talc	–	–

none, which is registered as a plant growth regulator under the commercial name Rastim 30 DKV containing 300 g of active ingredient per l kg. It is adjusted as a dispersion liquid concentrate (DKV) for dilution with water (DOLINAY, KOHAUT 2000; KUPEC et al. 2000). The holder of the patent and its producer is Istrochem Bratislava, joint stock company.

Five development samples of benzolinone prepared in powder form at concentrations from 0.01 to 0.5% were used for the assays (Table 1). In addition to these 5 benzolinone samples, other five samples were prepared as mixtures with indole butyric acid (IBA) and fungicides on the basis of the active ingredients captan and *Trichoderma harzianum* (Tables 1 and 2). The benzolinone samples and its mixtures were prepared in the department of final formulations at VUCHT Bratislava, joint stock company. The effects of benzolinone and its mixtures were verified at workplaces and are listed in Table 3, together with the experimental conditions of the tested species of plants.

One-year old herbaceous, semi-lignified and lignified shoots of tested species (Table 3) were adjusted to suitably long cuttings (6–14 cm) depending on the species. In sets with an equal number of cuttings/variant, they were treated with test samples of benzolinone and its mixtures in such a way that the base of the cuttings was moderately humidified with water and treated with the sample. The excess quantity of the sample was removed from the cuttings by slightly tapping on them and the treated and untreated cuttings were immediately planted in substrates whose composition is given in Table 3. Substrates used for propagation of carnations were sterilized in steam at 98°C for 2 h and those used with peat were sterilized chemically in a liquid containing 0.1% of the preparation Captan 50 WP or Supresivit, and this was done 3–5 days before the cuttings were planted. Species propagation at the different workplaces was carried out on propagation plots under controlled conditions and automatic spraying of the material.

The effects of benzolinone and its mixtures were evaluated in percent on the basis of satisfactory, weak and zero rooting of cuttings while the quality of the root system was also assessed. The effect of the samples was compared either with the standard Stimulator AS 1 or with non-stimulated control cuttings. The results were statistically processed by the analysis of variance and Student's *t*-test.

RESULTS

The stimulating action of benzolinone in powder form (P) has been confirmed by its research in 17 species of

Table 2. List of commercial preparations

Preparation	Active ingredient	Content of active ingredient	Final formulation	Producer
IBA	indole butyric acid	100%	PS	Sigma Co. USA
Captan 50 WP	Captan	50%	WP	Zeneca Agrochemicals Ltd., Great Britain
Stimulator AS 1	nicotinic acid + α-naphthylacetate K	0.06% 0.072%	P	ZAP Zahradkář Czech Republic
Supresivit	*Trichoderma harzianum* Rifai aggr. – spores	14 billion ex/g	WP	Fytovita, Co. Czech Republic

Abbreviations: PS – pure ingredient in powder, WP – wettable powder, P – powder

Table 3. List of herbs and woody plants and the conditions of research

Plant species	Variety	Period of cutting propagation	Number of cuttings/variant	Substrate	Experimental sites
Ficus schlechteri	–	June, September	420	peat 2:sand 1	BG CU
Dianthus sp.	Sacha, Virginia, Tanga	August, September	960–1,000	pearlite 9: polystyrene 1	Sempra
Dianthus sp.	Helas, Esperance Tanga	May	3,000	pearlite 3: polystyrene 1	Agrofrigor
Rosa canina L.	Alexander, Fairy, Lichtköning, Lucia, Průhonice, Queen Elizabeth, Schneewittchen	June, July	1,200	peat 2:sand 1: pearlite 1	RBIOG
Euonymus fortunei (TURCZ.) HAND – MAZZ.	–	July	210	sand 2:peat 1	VUCHT
Spiraea thunbergii SIEB.	–	July	150	sand 2:peat 1	VUCHT
Forsythia intermedia ZAB.	–	June, July	150	sand 2:peat 1	VUCHT
Viburnum farreri BUNGE	–	July	180	sand 2:peat 1	BG CU
Corylopsis pauciflora SIEB. & ZUCC.	–	July	300	sand	BG CU
Magnolia stellata (SIEB. & ZUCC.) MAXIM.	–	July	300	sand	BG CU
Acer saccharinum L. *Pyramidale*		June, July	120	peat 2–3:sand 1: pearlite 1*	RBIOG
Carpinus betulus L. *Fastigiata*		June, July	120	peat 2–3:sand 1: pearlite 1*	RBIOG
Prunus padus L. *Colorata*		June, July	60	peat 2–3:sand 1: pearlite 1*	RBIOG
Prunus kurilensis (MIYABE) MIYABE ex TAKEDA *Brilliant*		June, July	60	peat 2–3:sand 1: pearlite 1*	RBIOG
Actinidia arguta (SIEB. & ZUCC.) MIQ.	–	July	300	sand 2:peat 1	BG CU
Cherry rootstocks	P – HL – A	June, July	420	peat 2:and 1: pearlite 1	RBIP
Cotoneaster horizontalis DECNE.	–	June, July	150	sand 2:peat 1	SF BS
Philadelphus coronarius L.	–	July, August	125	sand 2:peat 1	SF BS

*The substrate was supplemented with 2 kg $CaCO_3.m^3$

BG CU – Botanical Garden of Comenius University, Bratislava, Slovakia; VUCHT – VUCHT Joint Stock Company, Bratislava, Slovakia; Agrofrigor – Agrofrigor, Dunajská Streda, Slovakia; SF BS – State Forests Breeding Station, Kmeťová, Slovakia; RBIOG – Research and Breeding Institute of Ornamental Gardening, Průhonice, Czech Republic; Sempra – Sempra, Olomouc, Czech Republic; RBIP – Research and Breeding Institute of Pomology, Holovousy, Czech Republic

ornamental plants, park and fruit woody species (Tables 4 and 5). The effect of benzolinone tested at five concentrations from 0.01% to 0.5% proved that the active ingredient preserved its auxinoid character also in this powder form and exerted a stimulating action on plant rhizogenesis (Figs. 4 and 5). This allowed to determine the optimum concentration at which the highest stimulating effect could be obtained in the species under study.

In the category of ornamental plants, the effect of benzolinone expressed as mean yield in well-rooted cuttings ranged from 44.5% in *Dianthus* sp. to 83.7% in *Rosa canina*, and was obtained within the concentration range of 0.01 to 0.1%, while in the species *Dianthus* sp. and *Ficus schlechsteri* it was 30.0–39.2% significantly higher in comparison with the controls (Table 4).

In the category of park ornamental woody species, the stimulating effects of benzolinone were evident within a concentration range of 0.01 to 0.1%, the highest being in the case of the species *Carpinus betulus Fastigiata*, *Spiraea thunbergii*, *Corylopsis pauciflora* and *Viburnum farreri*, at a concentration of 0.05%, and in *Forsythia intermedia* and *Euonymus fortunei* at a concentration

Table 4. Stimulatory effect (in %) of benzolinone on the rooting of ornamental plants (A), ornamental and park woody trees (B), fruit trees (C), and allochthonous woody trees (D)

Species		Treatment	Rooting (%)	Increase against control/standard (in %)	Benzolinone concentrations (in %)
Dianthus sp.	A	control	32.0	–	–
		benzolinone	44.5	39.1**	0.05–0.1
Ficus schlechteri	A	control	35.0	–	–
		benzolinone	45.5	30.0**	0.05
Rosa canina	A	control	76.5	–	–
		benzolinone	83.8	9.5	0.01–0.1
Carpinus betulus Fastigiata	B	AS 1 standard	91.7	–	–
		benzolinone	99.0	7.9	0.05
Corylopsis pauciflora	B	control	40.5	–	–
		benzolinone	70.0	72.8***	0.05
Euonymus fortunei	B	control	60.0	–	–
		benzolinone	76.7	27.8**	0.01
Forsythia intermedia	B	control	96.7	–	–
		benzolinone	100.0	3.4	0.01
Magnolia stellata	B	control	0.0	–	–
		benzolinone	16.7	16.7**	0.1
Spiraea thunbergii	B	control	46.7	–	–
		benzolinone	93.3	99.8***	0.05
Viburnum farreri	B	control	9.8	–	–
		benzolinone	20.0	104.1***	0.05
Actinidia arguta	C	control	16.9	–	–
		benzolinone	20.0	18.3	0.01
Cherry rootstocks	C	control	68.2	–	–
		benzolinone	86.7	27.1**	0.05
Cotoneaster horisontalis	D	AS 1 standard	93.0	–	–
		benzolinone	96.7	3.97	0.1–0.2
Philadelphus coronarius	D	AS 1 standard	73.0	–	–
		benzolinone	100.0	36.98**	0.1–0.2

**Significance of difference $P \leq 0.05$
***Significance of difference $P \leq 0.01$

of 0.01% (Table 4). An exception in this woody species category was *Magnolia stellata*, in which the best concentration proved to be 0.1% of benzolinone, the lowest yield in this species being 16.7% of rooted cuttings. This substance had a highly significant effect on the rhizogenesis of the species *Corylopsis pauciflora*, *Spirae thunbergii*, *Euonymus fortunei* and *Viburnum farreri* (Table 4). *Forsythia intermedia* and *Carpinus betulus Fastigiata*, species known for their naturally abundant root system even in non-stimulated cuttings, had substantially better rhizogenesis under the effects of benzolinone.

Table 5. Effects (in %) of mixtures (M) on the rooting of broad-leaved trees

Species	M1	M2	M3	M4	M5	AS 1 standard
Acer saccharinum Pyramidale	96.7	87.8	81.1	96.7	98.9	90.0
Prunus kurilensis Brilliant	78.3	90.0	90.8	90.0	81.7	73.4
Prunus padus Colorata	100.0	99.2	99.2	100.0	100.0	100.0
Average	91.7	92.3	90.4	95.6	93.5	87.8

Table 6. Effects (in %) of mixtures (M) on the rooting of broad-leaved trees (A), *Ficus schlechteri* (B) and *Dianthus* sp. (C)

Species	M1	M2	M3	M4	M5	AS 1 standard
A	91.7	92.3	90.4	95.6	93.5	87.8
B	55.0	50.0	55.0	60.0	65.0	75.0
C	87.3	88.5	–	92.4	–	83.8
Average	78.0	76.9	72.7	82.7	79.3	82.2

A – *Acer saccharinum Pyramidale, Prunus kurilensis Brilliant, Prunus padus Colorata*
B – *Ficus schlechteri*
C – *Dianthus* sp. (cv. Tanga, Virginia, Helas, Esperance, Sacha)

In the fruit woody species represented by two species, viz. *Actinidia arguta* and cherry rootstocks of the type P-HL-A, rooted cuttings had a yield of 20–86.7%, with benzolinone concentrations of 0.05 to 0.01%, which was an increase by 18.3 to 57.9% against the control. In the case of the allochthonous species *Cotoneaster horizontalis* and *Philadelphus coronarius*, a concentration of 0.1–0.2% of this substance ensured a stimulating effect of 96.7–100%. In the case of the latter species, this represented an increase by 37% against the control (Table 4). The total effectiveness of the benzolinone samples studied, in comparison with that of the control, showed a percentage increase in the rooted cuttings from 3.4% in the well-rooted species *Forsythia intermedia* to 104.1% in the problematic rooting of *Viburnum farreri*. By its effectiveness benzolinone was comparable with, and finally somewhat superior to, Stimulator AS-1 (Tables 4 and 5).

A higher yield of rooted cuttings was achieved in two-, but mainly three-component combinations of benzolinone with indole butyric acid (IBA) and fungicides on the basis of the active ingredients captan and *Trichoderma harzianum*. IBA in the mixture exerted a synergistic action on the effectiveness of benzolinone, which became evident not only in a higher yield of rooted cuttings but also in an improved root system of stimulated cuttings. The representation of fungicide components in the mixture, and their use for the sterilization of substrates, had a positive influence principally on the protection of the basal parts of the cuttings, thus preventing their infection and early mortality. The higher effectiveness of three-component than two-component mixtures in the propagation of *Dianthus* sp. and *Ficus schlechteri* is evident from Figs. 1 and 3 and in the case of deciduous woody species *Acer saccharinum Pyramidale*, *Prunus padus Colorata* and *Prunus kurilensis Brilliant* from Tables 5 and 6. A synergistic effect on the root quality of *Ficus schlechteri* cuttings was evident in the three-component combination benzolinone + IBA + Supresivit, enhancing their yield up to 65%, which is a highly significant increase by 62.5% in comparison with the control (Fig. 3). An excellent result was also obtained in the propagation of carnations. As there is a problem of varieties with different rooting capacity, declining in the order Tanga, Esperance, Virginia, Helas and Sacha (Fig. 2), a positive and significant effect of the mixture was observed mainly in well-rooted cuttings of category I (Fig. 1). With the two-component mixture benzolinone + IBA, the percentage increase in rooted cuttings in all the five cultivars of carnations represented an increase by 7.4%, with the mixture benzolinone + captan it was 17.1% and with the three-component mixture

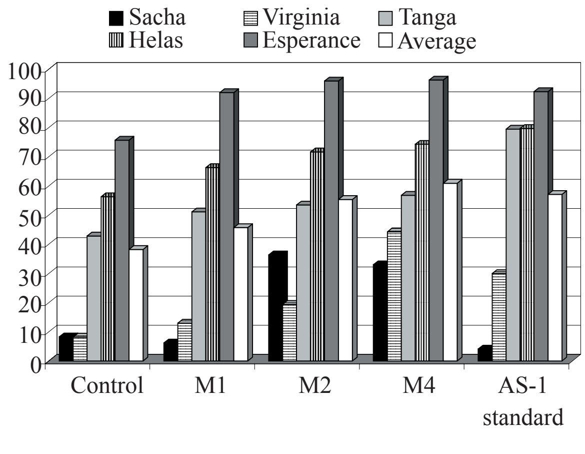


Fig. 1. Effects (in %) of mixtures (M) on the well rooted cuttings of *Dianthus* sp. (cv. Sacha, Virginia, Tanga, Helas, Esperance)

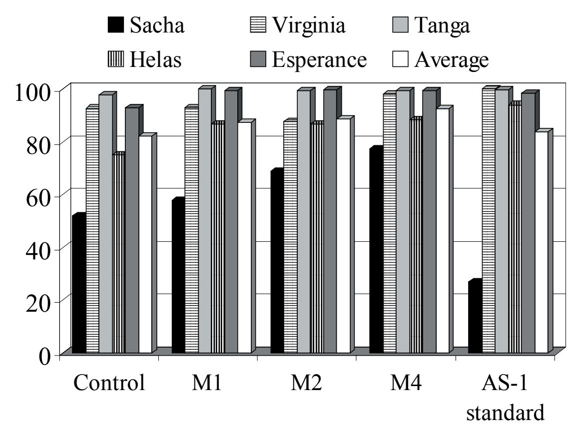


Fig. 2. Effects (in %) of mixtures (M) on all rooted cuttings of *Dianthus* sp. (cv. Sacha, Virginia, Tanga, Helas, Esperance)

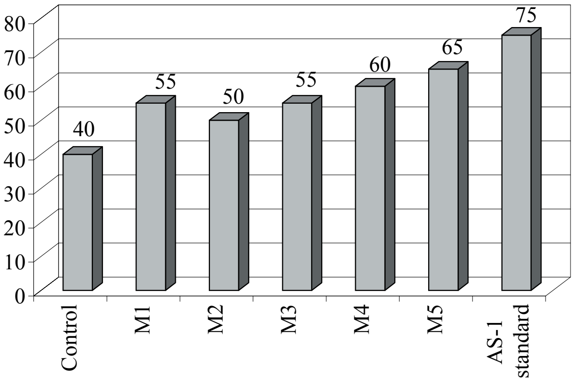


Fig. 3. Effects (in %) of mixtures (M) on *Ficus schlechteri* rooting

M1 = benzolinone + IBA, M2 = benzolinone + captan, M3 = benzolinone + *T. harzianum,* M4 = benzolinone + IBA + captan, M5 = benzolinone + IBA + *T. harzianum*

benzolinone + IBA + captan it amounted to 22.6% against the control. The three-component mixture ultimately proved more effective than the comparative standard Stimulator AS1 (Fig. 2). Quantitatively, the positive effect of the benzolinone mixture could be best evaluated in the cultivars Sacha and Helas (Fig. 1), which had the lowest rooting capacity. The three-component mixtures of benzolinone with IBA and fungicides under study also confirmed stimulating effects on the rooting of deciduous woody species. As evident from Table 5, the highest stimulating effect of the mixtures was observed in the species *Prunus padus Colorata*, with rooting yield of 99 to 100%, followed by *Acer saccharinum* with 81.1–98.9%, and *Prunus kurilensis Brilliant* with the lowest yield of 78.3–90.8%. Evaluating the total effectiveness of all the mixtures tested, best were three-component combinations on the basis of benzolinone + IBA and the fungicide Captan 50 WP, or the biofungicide Supresivit.

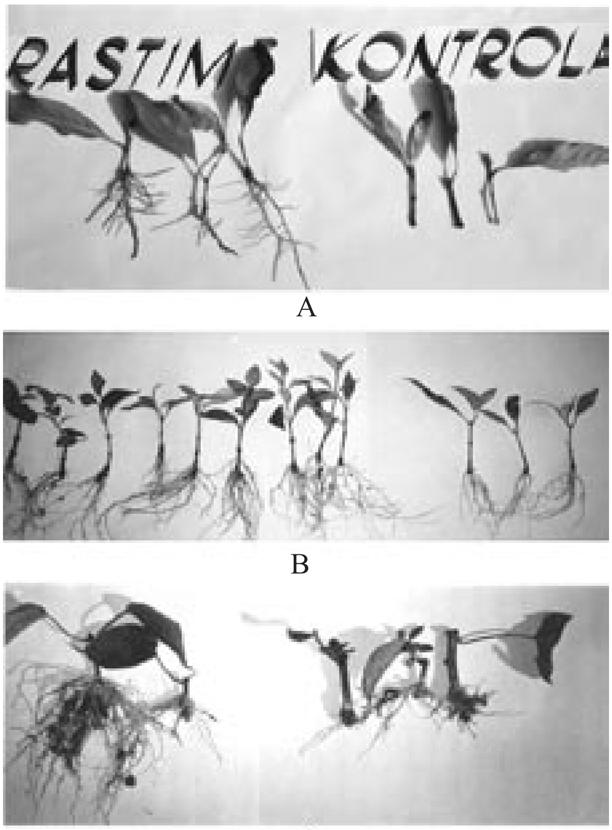
DISCUSSION

It is generally known that the formation of adventitious roots in plants is controlled by growth substances (DAVIS, HASSIG 1990) and auxins are the principal hormones playing a direct role in this process (GASPAR, HOFINGER 1988). This is also supported by the results of research on benzolinone, which was verified in a new powder formulation (P) during the vegetative propagation of 17 species of ornamental plants, park and fruit woody species. In this powder form required also by the propagation practice, benzolinone has maintained its auxinoid growth activity, which was confirmed in a dispersion formulation (DKV) by the authors HENSELOVÁ et al. (1989) and RAUSCHEROVÁ et al. (1991).

The variable percentage of rooting in the species ranging from 16.7% (*Magnolia stellata*) to 100% (*Forsythia intermedia* and *Philadelphus coronarius*) can be explained by a variable content of not only endogenous auxins but also inhibitors. Differences in the rooting of the species point to the existence of relationships between the content of endogenous auxins and their rooting capacity ascertained by ŠEBÁNEK et al. (1991). According to ŠEBÁNEK and KRÁLIK (1983), the phytohormonal preparation for the formation of adventitious roots is related to an increased level of auxins at their base. In these authors' opinion, auxins indicate the meristematic activity of tissues and enhance the supply of plastic substances at the sites of root formation. An exogenic application of synthetic auxin, as it is also verified in our work with benzolinone, may act jointly with endogenous auxin and thus stimulate the formation of adventitious roots.

The species like *Carpinus betulus Fastigiata*, *Rosa canina*, *Forsythia intermedia* and *Cotoneaster horizontalis*, noted for their natural abundance of roots ranging between 76.5 and 96.7%, probably contain a high level of endogenous auxins. Among the species with lower rooting capacity we may include *Ficus schlechteri* from among the ornamental plants, some cultivars of *Dianthus* sp. (Sacha and Helas) and *Corylopsis pauciflora* and *Spiraea thunbergii* from the park ornamental woody species whose rooting capacity without stimulation ranged between 32.0 and 54.9%. A special category was represented by species with low or zero root formation among which, in view of the results obtained, we may include *Magnolia stellata*, *Viburnum farreri* and *Actinidia arguta*. As regards the species *Viburnum farreri*, we admit that the less than optimum humidity and temperature conditions may partly have been responsible for the low percentage of rooting, as they caused a precocious fall of leaves and rotting of the cutting bases. The tests demonstrated not only interspecific differences in rooting, but also in the sensitivity of various cultivars of the same species, as was the case of *Dianthus* sp. In cultivars with higher regeneration capacity, such as Esperance, Tanga and Virginia, the effect of benzolinone failed to be of statistical significance in the yields of rooted cuttings, but it was visible in the quality of the root system of stimulated cuttings as regards the number of roots and their length. In the case of cultivars with lowered rooting, such as Helas and Sacha, the benzolinone effect was also significant in a higher number of rooted cuttings. Such differences in rooting were also found by KRÁLIK et al. (1989) in poplars under the influence of the Cultar preparation, and by MARINO (1988) in three species of cherries where the IBA and paclobutrazol mixture proved effective in only one species.

It is accepted that a positive effect of stimulators on the rooting process in plants is achieved if other conditions are adhered to – such as optimum temperature of the atmosphere and substrate, adequate moisture of the latter, type of substrate and, according to TURECKAYA and POLIKARPOVA (1968), also the ripeness of cuttings, including the date of cutting which is determined by the growth stage. We may state from the results obtained that the concentration



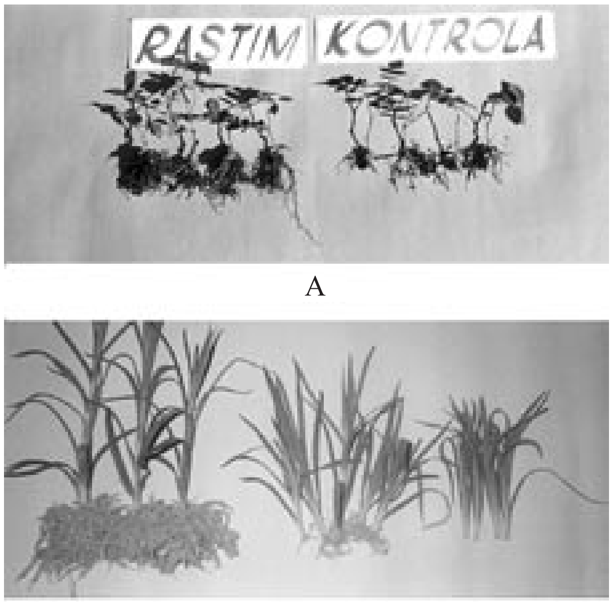
A

B

C

Fig. 4. Effect of benzolinone (Rastim) on the rooting of cuttings of park woody species

A *Magnolia stellata*, B *Forsythia intermedia*, *C Viburnum farreri.* Treated cuttings (left), untreated cuttings (right)



A

B

Fig. 5. Effect of benzolinone (Rastim) on the rooting of cuttings of ornamental species

A *Rosa canina,* B *Dianthus* sp. Treated cuttings (left), untreated cuttings (right)

of benzolinone itself, as well as of its mixture with IBA and fungicides, has an essential impact on the percentage yield of rooted cuttings while an important role was played by the degree of their ripeness. Semi-lignified to lignified cuttings rooted better than immature ones. For instance for maple propagation CAREY (1974) and CARVILLE (1975) recommended either semi-hard cuttings in June and July, or hard cuttings in February, but a growth stimulator application was absolutely essential in the latter case. In lignified cuttings, such as the allochthonous species *Cotoneaster horisontalis* and *Philadelphus coronarius*, and *Magnolia stellata*, higher concentrations of 0.1% to 0.2% proved more efficient, while on the contrary, lower concentrations – below 0.1% – were more suitable for less mature cuttings. We presume that the lower rooting of some species, e.g. *Magnolia stellata* and *Corylopsis pauciflora*, may have been due to the fact that the cuttings came from mother trees aged 10 years and more whose regenerative capacity was weakened. It is also supported by the results reported by KRÁLIK et al. (1989), who found that 95% of cuttings of *Ligustrum vulgare* from two years old plants took root while the value was only 45 to 65% in the case of those coming from individuals older than 10 years. Similarly, PETŘÍKOVÁ (1989) reported a higher rooting percentage in propagating the medicinal plant lavender (*Levandula officinalis*) from one-year old cuttings than from older ones. In more lignified cuttings the lower stimulating effect of synthetic auxin may also be affected by endogenous cytokinins just as it was in the case of benzolinone (ŠEBÁNEK et al. 1983). Likewise according to ŠEBÁNEK and KRÁLIK (1983), an earlier onset of endogenous dormancy may inhibit the formation of adventitious roots, a fact that cannot be excluded in the case of *Magnolia stellata*, where maximally l6.7% cuttings took root and not a single one of those not stimulated.

Indole butyric acid (IBA), represented in two- and three-component combinations with benzolinone, acted synergistically with the latter, whereby the rooting percentage of cuttings increased. This confirmed that IBA is one of the widely applicable root-forming stimulants. In the majority of cases, a combination of several active ingredients leads to a synergistic stimulating effect. Similar results of synergism between IBA and Triacontanol were reported by TANTOS et al. (2000) for the rooting of *Malus domestica* and *Cerasus vulgaris*, and of synergism between IBA and the growth retardants daminozid, paclobutrazol and tradimephone discovered by PAN and ZHAO (1994). With stimulated cuttings, most of the species form a higher-quality root system, which also provides better conditions for cuttings to take root after they are transplanted and this, in turn, ensures a higher plant production. The quality of the root system is often a determinant factor for the plant survival percentage and it is also in agreement with the results of OBDRŽÁLEK (1987), who found in the species *Syringa vulgaris* L. cv. Späth that the 1st category cuttings with best root system survived in 88–90% of cases while maximally 35–40% of those of the 2nd category survived. Deciduous woody species of the genera *Carpinus* and *Prunus* which formed very abundant root systems with benzolinone stimulation and its mixtures, hibernated better and even at lower temperatures (KOBERT 1980), and according to OBDRŽÁLEK (1987) so did the trees of the genus *Betula, Fagus* and *Malus*.

According to TURECKAYA and POLIKARPOVA (1968), the date of cutting ranges between June 10 and 25, nevertheless, it depends on the onset of vegetation in the given year. In the majority of species we cultivated, the months were June and July. An exception was the case of park woody species that were cut in August. Effective was also the propagation of *Dianthus* sp. and *Ficus schlechteri* in the months of September and May, but this involves species whose vegetative propagation through cuttings is made possible by glasshouse conditions. We can agree with Schönberg's opinion (1963) when he stresses the importance of the period of cutting. For example, in the species *Prunus mahaleb* he achieved 93.3% rooting in May while in June and July it was not more than 76.7%. In cherry rootstocks we also propagated in June and July through benzolinone stimulation we obtained a somewhat higher yield – 86.7% of rooted cuttings. Cuttings from top or middle parts of less mature shoots were more frequently susceptible to earlier rot and mortality which caused a considerable loss and lowered the rooting percentage. We are therefore convinced that maturity of cuttings is one of the preconditions of their good-quality rooting, a fact confirmed by Obdržálek's experience (1983) in propagating Japanese maples when he found that cuttings taken shortly before the growth was completed or immediately after it had the best root system and, on the contrary, those taken at the time of intensive growth had unfavorable yields.

The type of stimulator used as well as the method of stimulation are of equal importance for the final result. As regards the species that root in a short time, such as the cultivars of *Dianthus* sp. in our case that took root in 22 days on the basis of experience at the workplaces Sempra Olomouc and Agrofrigor Dunajská Streda, a short-term stimulation proved very successful whether it was in the form of powder – our benzolinone and Stimulator AS1 – or stimulation lasting but a few seconds with concentrated alcoholic solutions of auxinoid mixtures. Benzolinone and its mixtures exert a very good stimulating effect in the species that root in a longer time where in dependence on the concentration of active ingredients stimulation of the cutting bases brings about their gradual liberation and prolonged action in the plant root-forming process.

In the benzolinone mixture, the active ingredients of the fungicide captan and *Trichoderma harzianum* played a protective role and lowered the percentage of precocious rot of cuttings. The three-component mixture of benzolinone + IBA + captan proved beneficial for substrates without peat, a fact also confirmed by the results of propagation of *Dianthus* sp. and, on the other hand, a biofungicide mixture on the basis of *Trichoderma harzianum* was more effective in substrates with a higher proportion of peat, as proved by the results of propagating the species *Ficus schlechteri* and the woody plant species *Acer saccharinum Pyramidale, Prunus kurilensis Brilliant* and *Prunus padus Colorata*. Peat-based substrates are probably less resistant to an epidemic spread of pathogens that frequently the cause of cutting losses. This may be prevented by treatment of the substrate with fungicide preparations prior to or during plant propagation. Therefore, the presence of the fungicide component in the benzolinone under study could increase the preventive effect principally at the base of the cutting. Very satisfactory results of ornamental plant propagation with the application of biofungicides on the basis of *Pythium oligandrum* and *Trichoderma harzianum* into the soil were attained by DUŠKOVÁ (1995).

The mean yield of well-rooted cuttings of deciduous woody species that rooted within 4–6 weeks under the action of a benzolinone mixture and were fit to be transplanted was very high and ranged between 90.4 and 95.6%, which corroborates Spethman's opinion (1982) that the species of the genera *Acer* and *Prunus* belong to those with a high rooting potential. OBDRŽÁLEK (1983), applying 1% IBA and the mixture IBA + NAA + Captan to Japanese maples, achieved a 75% yield of rooted cuttings, which amounted to a 32% increase against the control. In comparison with the standard Stimulator AS 1 two- and three-component mixtures of benzolinone as a result of its final adjustment (P) yielded the same or even somewhat higher stimulating effect. On the basis of the results obtained, we have proposed and recommended three-component benzolinone mixtures for state verification tests.

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Synergický účinok benzolinonu s IBA a fungicídmi na vegetatívne množenie okrasných rastlín, parkových a ovocných drevín

ABSTRAKT: Sledoval sa vplyv desiatich vývojových vzoriek benzolinonu (3-benzyloxykarbonyl-metyl)-2-benzotiazolinonu upravených do formy prášku a jeho zmesí s kyselinou indolylmaslovou biofungicídom Supresivit a fungicídom Captan 50 WP (ich zloženie je uvedené v tab. 1 a 2) na zakoreňovanie 17 druhov okrasných rastlín, parkových a ovocných drevín (tab. 3). Jednoročné polozdrevnatené až zdrevnatené výhonky overovaných druhov boli upravené na 6–14 cm dlhé odrezky v závislosti od druhu. Bázy odrezkov sa ošetrili vzorkami a ošetrené ako aj neošetrené odrezky sa vysadili do substrátov (ich zloženie je uvedené v tab. 3). Účinok benzolinonu a jeho zmesí sa porovnal s účinkom prípravku Stimulátor AS 1 a s kontrolou. Ukázalo sa, že benzolinon mal pozitívny vplyv na rizogenézu odrezkov overovaných druhov rastlín aj v práškovej formulácii (tab. 4 a 5). V kategórii okrasných rastlín sa vplyvom benzolinonu dosiahla výťažnosť zakorenených odrezkov od 44,5 % (*Dianthus* sp.) po 83,7 % (*Rosa canina*) pri koncentračnom rozmedzí 0,01–0,1 % (tab. 4). V kategórii parkových drevín sa stimulačné účinky benzolinonu prejavili v rovnakom koncentračnom rozpätí ako u okrasných rastlín, pričom pri druhoch *Carpinus betulus Fastigiata*, *Spiraea thunbergii*, *Corylopsis pauciflora* a *Viburnum farreri* sa dosiahol najlepší stimulačný účinok pri koncentrácii 0,05 %. Najnižšia výťažnosť zakorenených odrezkov sa dosiahla u druhu *Magnolia stellata* (16,7 %) a najvyššia u druhu *Forsythia intermedia* (100 %). Ovocné dreviny, zastúpené druhom *Actinidia arguta* a čerešňovými podnožami typu P-HL-A, mali výťažnosť 20 %, resp. 86,7 %, a dva druhy allochtónnych drevín mali výťažnosť zakorenených odrezkov 96,7 % (*Cotoneaster horizontalis*) a 100 % (*Philadelphus coronarius*). U ťažšie koreniacich druhov (*Magnolia stellata*, *Viburnum farreri* a *Actinidia arguta*) benzolinon preukazne zvyšoval percento zakorenených odrezkov a ovplyvnil aj kvalitu koreňovej sústavy, u druhov s prirodzene vysokou koreniacou schopnosťou (*Forsythia intermedia* a *Philadelphus coronarius*) sa jeho vplyv prejavil hlavne v kvalite koreňovej sústavy. Dvoj- a trojzložkové zmesi benzolinonu pôsobili synergicky, čím sa zvyšovalo percento výťažnosti zakorenených odrezkov, v prípade jeho zmesí s fungicídmi sa zabezpečila aj ochrana odrezkov a znížilo sa tým percento ich zahnívania a predčasného odumierania. Najpreukaznejšie stimulačné účinky na zakoreňovanie odrezkov *Dianthus* sp., *Ficus schlechteri* a opadavých listnatých drevín *Acer saccharinum Pyramidale*, *Prunus padus Colorata* a *Prunus kurilensis Brilliant* mali trojzložkové zmesi (tab. 5 a 6 a obr. 1–3), a preto boli odporučené pre štátne overovacie pokusy s cieľom získania ich registrácie.

Kľúčové slová: benzolinon; kyselina indolylmaslová (IBA); captan; *Trichoderma harzianum*; vegetatívne množenie; okrasné rastliny; parkové a ovocné dreviny

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